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BEXUS User Manual

Document ID: BX-BEXUS_user_manual-v6_1-30Aug10

Version:	Issue Date:	Document Type:	Valid from:
6.1	**30 August 2010**	**Spec**	**1 September 2010**

Current version issued by:
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Current version approved by:
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Distribution:

Change Record

Version	Date	Changed chapters	Remarks
Draft	2007-02-07		
2	2007-08-23		
3	2007-11-23	all	
4.1	2007-11-30	all	
4.2	2007-12-05		O. Persson
4.3	2007-12-11		O. Persson
4.4			
4.5			
4.6	2008-11-12		O. Persson
4.7	2008-12-08		A. Stamminger
4.8	2008-12-11	all	O. Persson
4.9	2009-02-08	all	H. Page
5.0	2009-02-27	4.4.2, 4.5, 6.2, 6.3.2 8.5.3	O.Persson
6.0	2009-12-04	all	M. Fittock
6.1	2010-08-30	6.1, 6.2, 6.3, 6.6.1, 8.6	M. Fittock, M. Uitendaal

Abstract: This document has been created by EuroLaunch to aid experimenters taking part in a BEXUS flight as part of the REXUS/BEXUS Programme. It is continually updated and developed in order to serve the experimenters and operators better. It describes important information about flights for experimenters, interface details, design guidelines, and testing.

Keywords: BEXUS, manual, interface, EuroLaunch, testing, design

This is not an ICD document.

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1 INTRODUCTION

The Swedish/German balloon program BEXUS provides periodically recurring flight opportunities for student experiments. Conducted by EuroLaunch, BEXUS is an easily accessible experiment facility giving a few hours of high atmosphere flight.

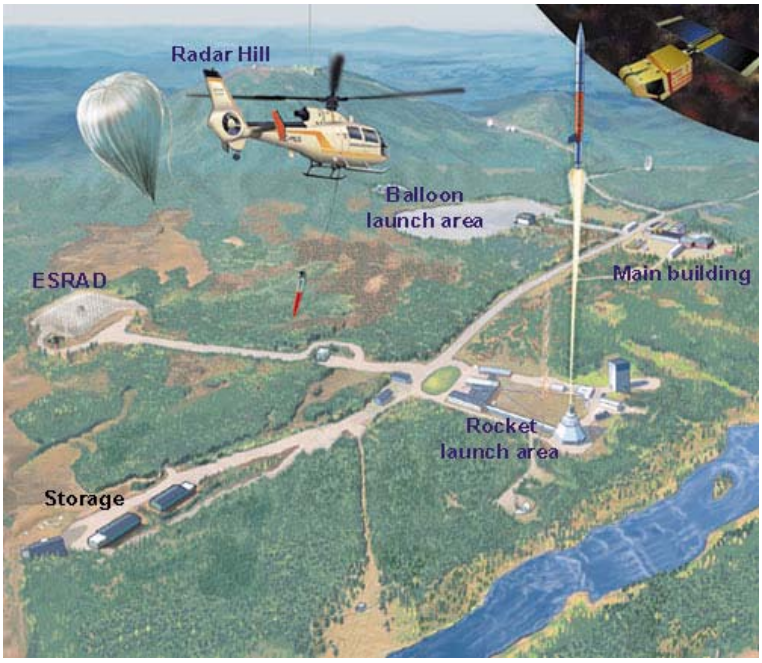

Figure 1-1: Esrange launch site

The payload is modularised to provide simple interfaces, good flexibility and independence between experiments. All payload service systems necessary for telecommunication, payload control, and recovery are included in the system. High speed telemetry and up-link command control of experiments is provided.

This document describes all the necessary information for a user of the BEXUS system, including the services offered by EuroLaunch. It defines the requirements that apply to the BEXUS experiment modules and gives design recommendations. It also includes a description of the BEXUS system, the programmatic elements, the pre-flight tests and the campaign schedule and, finally, there is a chapter on quality assurance and safety.

2 ALWAYS READ THIS

There is plenty of useful information in this manual. Make sure that you have found and understood the meaning of the following information.

Experiment safety

If there are hazardous items such as chemicals, free-falling objects, lasers, radiation, etc. included in the experiments, there may be a need for further investigation by the Esrange Safety Board. This may take some time and should be done early in the design process.

Durability of your experiment

During the pre-flight tests and the count down, the experiments will be turned on and off several times over the course of many hours and multiple days. Make sure that there is enough battery, memory, etc. to survive these activities, in addition to that which is required for the flight.

Transmitters

All equipment that emits RF must have Esrange permission to do so.

Radio Frequency interference test

After the RF test it is not permitted to make any changes to the gondola or experiments before flight. If you miss this test during the campaign preparation phase, it may be necessary to remove your experiment or fly the gondola with your experiment turned off.

If your experiment disturbs any of the flight systems, it will not be flown at all.

Weather constraints

It is not possible to guarantee a launch during any specific week, due to weather constraints. Make sure that your experiment can be operated by Esrange staff, in case the launch is postponed beyond the date when you have to leave.

Planning

It is essential to have a build-up plan and checklists for your experiment. Without these, there is a significant risk of failures and delays during the campaign week.

Safety on balloon pad

No one is allowed on the balloon pad without the permission of the Operations Officer.

In the final 30 minutes before launch, there is no more access to the experiments.

Flight Requirements Plan

This is a document that is compiled by the EuroLaunch Project Management based on input and requests from all experimenters. Without good information, well before the campaign, it might be impossible to fulfil a requirement such as the provision of gases, special tools, etc.

Our goal is to have a successful and enjoyable campaign with all teams and their experiments. You are always welcome to contact us with any questions.

2.1 Definitions

The BEXUS system consists of the following components according to the EuroLaunch definition.

BEXUS	The complete integrated vehicle to perform the flight.
Ground Equipment	BEXUS supporting systems on ground.
EBASS	Balloon service system.
E-Link	Ethernet up & downlink.
Esrange Facilities	Equipment used to monitor and control the flight, and telemetry receiving equipment.
Ground Support Equipment	Equipment used to control and communicate with various modules during test and count down.
Balloon	The parts of BEXUS giving the lifting force.
Payload	Experiment modules and all subsystems.
Subsystems	All systems required for flight control, recovery, and telemetry.
Experiment Gondola	Experiment equipment and the carrier structure.

2.2 References

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[10] Vallado, David A.: *Fundamentals of Astrodynamics and Applications* (McGraw-Hill Companies, Inc, 1997)

NOTE: All references documents can be found on the BEXUS teamsite along with the manual. The ECSS references link directly to the documents themselves, firstly though, in order to access the documents, registration is required (this is easy and free for the user).

2.4 Abbreviations

AGT	Argos GPS and ATC Transponder
AIT	Assembly, Integration and Test
APID	Application Identifier
ASAP	As Soon As Possible
ATC	Air Traffic Control
BCR	BEXUS Campaign Report
BEXUS	Balloon EXperiment for University Students
CD	Count Down
CDR	Critical Design Review
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EAR	Experiment Acceptance Review
EAT	Experiment Acceptance Test
EBASS	Balloon piloting system
ECEF	Earth Centered, Earth Fixed
EGon	Esrange balloon gondola
EIT	Electrical Interface Test
E-Link	Ethernet up & downlink system
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESA	European Space Agency
ESD	Electrostatic Sensitive Device
ESRANGE	European Sounding Rocket Launching Range
FAR	Flight Acceptance Review
FRP	Flight Requirements Plan
FRR	Flight Readiness Review
FST	Flight Simulation Test
GND	Ground
GSE	Ground Support Equipment
H/W	Hardware
HCD	Hot Countdown
HERCULES	Balloon launch vehicle
HK	House Keeping
I/F	Interface
ICD	Interface control document
IFU	Interface Unit
LOS	Line of sight
LT	Local Time
LTC	Local Tangent Coordinate System
Mbps	Mega bits per second
MFH	Mission Flight Handbook

MORABA	Mobile Raketenbasis (DLR)
MTR	Mid Term Report
NC	Not Connected
NCR	Non Conformance Report
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
PFR	Post Flight Report
PI	Principal Investigator
PST	Payload System Test
QA	Quality Assurance
RNRZ	Randomized NRZ (a signalling modulation)
RX	Receiver
S/W	Software
SED	Student Experiment Documentation
SNSB	Swedish National Space Board
SSC	Swedish Space Corporation
STW	Student Training Week
T	Time before and after launch noted with + or -
TBC	To Be Confirmed
TBD	To Be Determined
TC	Tele-Command
TM	Telemetry
TX	Transmission
WGS84	World Geodetic System 1984
WT	Walky Talky, handheld radio

3 BEXUS PROJECT OVERVIEW AND MILESTONES

3.1 Project Organisation

The technical support in the integration and testing phase, as well as the campaign management and operations, is provided by **EuroLaunch**. EuroLaunch was founded in 2003 and is a joint venture of Swedish Space Corporation (SSC) and the **Mobile Rocket Base** of (**MORABA)** the German Aerospace Center (DLR). The DLR service part concerning experiment integration, testing and student support is provided by the **Institute of Space Systems RY** (DLR) in Bremen. When EuroLaunch is mentioned in this document, it means that all three institutions (SSC, MORABA and the RY) may be involved.

The BEXUS balloons are launched from the European Sounding Rocket Launching Range Esrange of SSC, near Kiruna in Northern Sweden.

The scientific evaluation of the experiment proposals and the financial support of the students are the responsibility of the **German Space Agency (DLR)** and the **Swedish National Space Board (SNSB),** in the latter case through cooperation with the **European Space Agency (ESA)**.

3.2 BEXUS Flight Ticket

In the **BEXUS "flight ticket",** which is offered to the international student community, the following services are included:

- General management and planning of the BEXUS project
- Provision of launch vehicle and subsystems necessary for a flight mission of 2-5 hours with recovery.
- Integration of participating modules into the flight configured payload and pre-flight testing of payload (TM, TC, flight simulation test).
- Assembly of the payload into the gondola and pre-flight testing at the Esrange launch site
- Provision of laboratory facilities at the Esrange launch site.
- Launch and recovery of payload.
- Data acquisition with provisions of real time, quick-look and replay data from gondola and payload subsystems.
- Disassembly of payload and return of experiments.
- BEXUS Campaign report.

3.3 Experimenter's Role

Once selected to participate in the REXUS/BEXUS programme, the teams become a part of the mission team. Their primary responsibility is to ensure the timely delivery of their portion of the scientific payload in good order. This responsibility extends to defining the investigation, providing the instrumentation, timely processing of data, and publishing of results. The experimenters must also contribute to establishing and conducting the operational programme through correspondence and fulfilment of the documentation requirements.

The successful operation of experiments is vital to the overall success of the REXUS/BEXUS missions. EuroLaunch supports the teams in order to see the good scientific returns. Information and expertise is available where required for assisting decisions relating to design, component, materials, operation, and any other mission related issues. Final decisions are normally left to the experimenters but if required (by safety or otherwise), EuroLaunch withholds the right to enforce decisions on any issue. Before flight, the experimenters must successfully convince EuroLaunch through testing, simulation, and documentation that their experiment is fit and safe for flight.

The experimenters are responsible for developing and providing the scientific payloads and support equipment provided. EuroLaunch can aide with many of these issues but the team is responsible for ensuring that these are organized in a timely manner. They are also responsible for ensuring that the experiments conform to all required electrical and mechanical interface specifications, meets safety requirements, and survives the flight. EuroLaunch assists in all these issues where possible but the experimenters must keep in mind that ensuring the resolution of issues is their responsibility.

3.4 Project Planning

A detailed project plan and time schedule will be released by EuroLaunch as soon as possible after the selection workshop. These will be regularly updated during the project.

At EuroLaunch the following key positions will be assigned for every project:

- Project Manager
- Payload Manager
- Mechanical Design Responsible
- Electrical Design Responsible
- Telemetry (TM) and Telecommand (TC) Systems Responsible

One person can have dual assignments.

Additional positions will be assigned during the campaign (see chapter 8.5).

3.5 Student Experiment Documentation (SED)

The SED provides EuroLaunch and other stakeholders from SNSB, ESA and DLR with all the important information on a particular experiment. During the phases of experiment development, production and flight, the SED will be the main documentation for students to describe their experiment. All documentation relating the requirements of this document can be found at the REXUS/BEXUS teamsite.

4 BEXUS SYSTEM

4.1 BEXUS flight configuration

The typical BEXUS configuration consists of a 12.000 m^3 balloon, a cutter, a parachute system, the Esrange Balloon Service System (EBASS), the flight train, Argos GPS and ATC Transponder (AGT), a radar reflector, and an experiment gondola. The total length of this system is up to 75 m. (Figure 4-1).

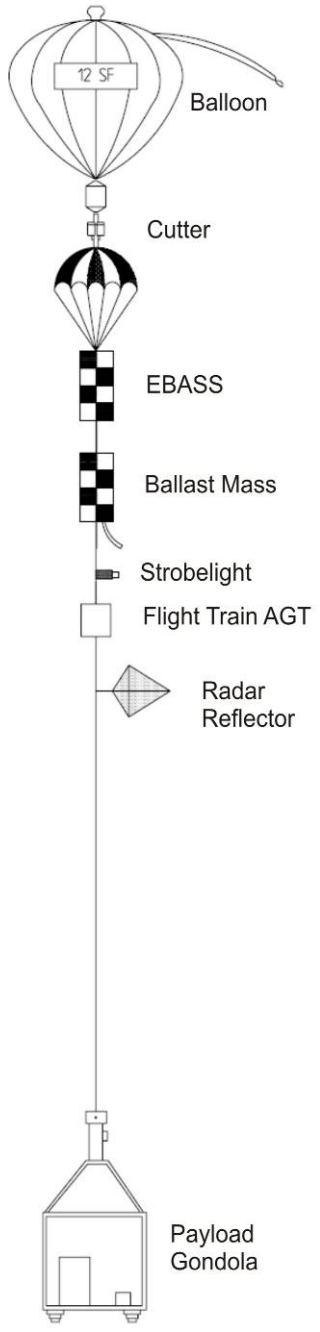

Figure 4-1: BEXUS Vehicle

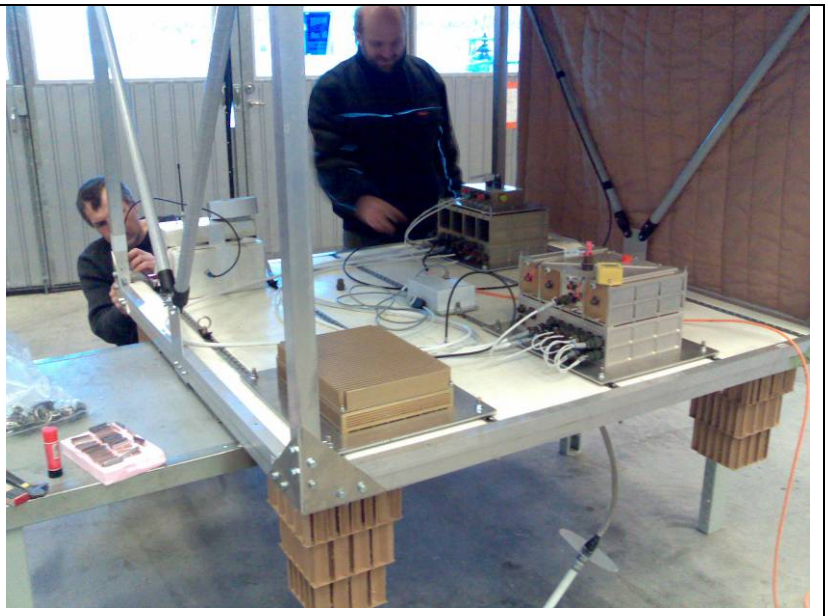

Figure 4-2: BEXUS Experiment Gondola

Figure 4-3: Hercules Launch Vehicle with Gondola

4.2 Gondolas

There are two different experiment gondolas available for the BEXUS programme:

Esrange gondola (Egon) is a medium-sized gondola with dimensions of 1.5 m x 1.5 m x 1.0 m. It is designed to carry experiment loads up to 200 kg.

Small Egon (S-Egon) is small-sized gondola with dimensions of 0.75 m x 0.75 m x 0.65 m. It is designed to carry payloads up to 100 kg.

4.3 Homing Aid

The flight train and balloon envelope are equipped with separate ARGOS/GPS-receiver/transmitters (AGT), from which the position information can be assessed by satellite both during the flight and after landing. The GPS position is also transmitted via the telemetry stream through the EBASS system. The recovery team in the helicopter can be equipped with a homing-receiver in order to acquire the GPS position for a quick and easy way to locate the payload.

Both the balloon envelope and the payload are equipped with an air traffic transponder and altitude encoder, to aid tracking.

4.4 Flight sequence

For details of previous flights, please refer to the past campaign reports and flight data. If these can not be found on the REXUS/BEXUS webpage or teamsite, they can be made available upon request.

4.4.1 Launch

The payload is held by a launch vehicle and is released when the balloon begins its ascent.

Figure 4-4: Dynamic Launch with Hercules Launch Vehicle

4.4.2 Ascent phase

The nominal ascent speed is 5m/s. Depending on float altitude and variations in speed, this phase can take up to 2 hours. A slight oscillating movement is experienced. Expect an initial drift above ground of 5-10m/s

4.4.3 Float phase

When the total mass of the system and the buoyancy of the gas reaches equilibrium, the ascent phase stops. During float there are only minor changes in altitude (±200m). Once the sun sets, the balloon will begin to descend due to the cooling of the gas.

The payload mass influences the maximum altitude. The final altitude is calculated shortly before launch and may vary between 25 and 35 km. The nominal flight time is one to four hours.

4.4.4 Descent phase

To end the flight, the cutter is activated, causing the balloon to separate from the rest of the flight train and rip open. There is a parachute system that brings down everything below the cutting device.

The descent speed is high from the start, due to the thin atmosphere. Closer to the ground, it will stabilize at approximately 8 m/s.

4.4.5 Landing

Landing is always planned to be in sparsely-populated areas, preferably without any lakes.

The landing velocity is approximately 8 m/s. This is equivalent to a drop from approximately 3 m. There is a shock-absorbing material at the bottom of the gondola that lowers the shock load at landing. Nominally, the landing is gentle with no damage to the experiments.

On rare occasions we have seen landing shocks up to 35 g when landing in rocky terrain. A water landing is softer but comes with another problem, since the gondola is not watertight.

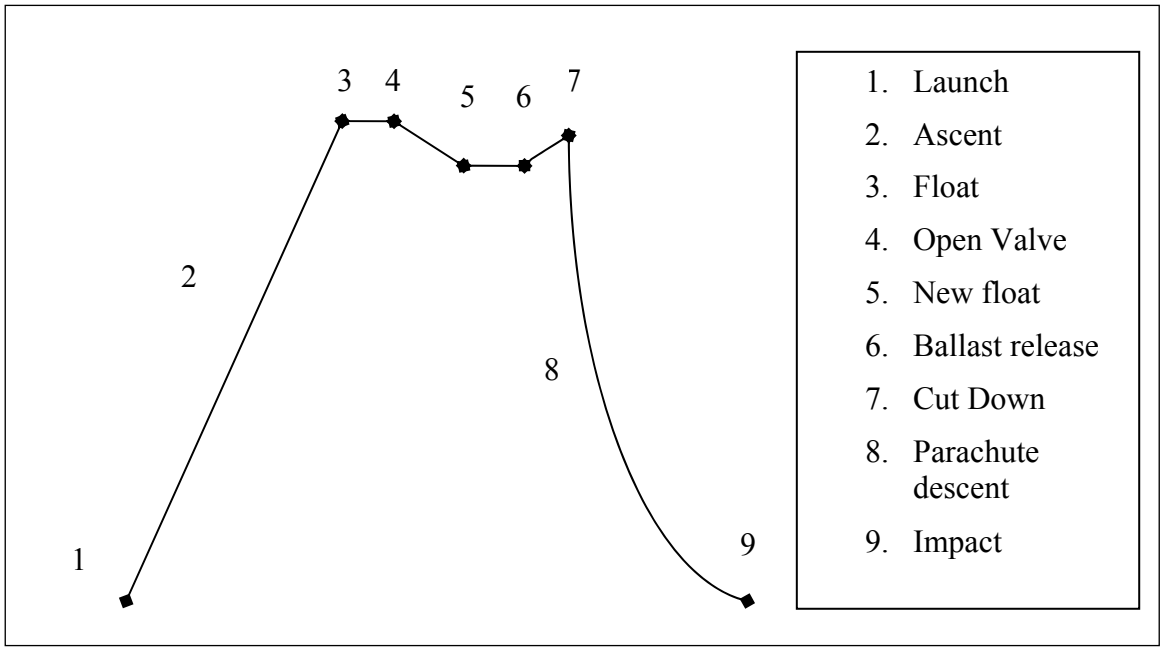

Figure 4-5: BEXUS Flight Profile

The performance of the BEXUS balloon may be adapted to the respective mission requirements. Valve (4) and ballast release (6) operations are optional and not normally flown on BEXUS.

4.5 Flight trajectory

The total distance covered is different for all missions. Since all flight systems depend of Line Of Sight (LOS) between Esrange and the gondola, the maximum range is about 400 km. Flight profiles are available in numerical form upon request.

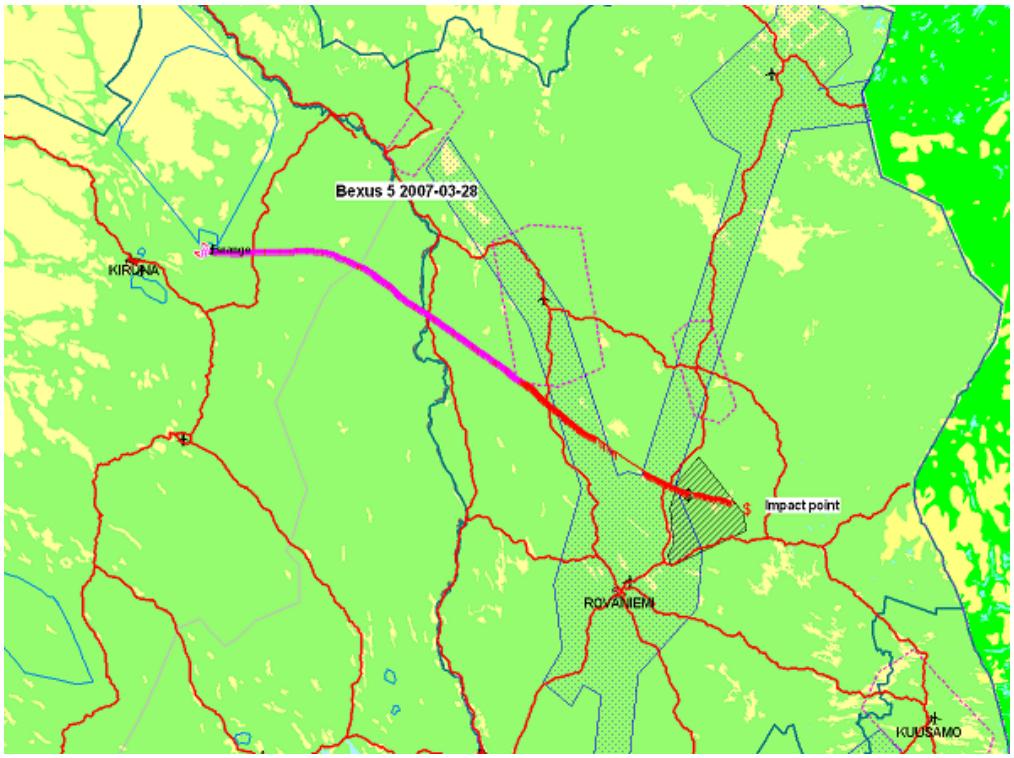

Figure 4-6: Example of BEXUS-5 Flight Trajectory (March 2007)

4.6 Recovery

The gondola will be picked up by helicopter for further transport by truck back to Esrange. The payload is normally brought back to Esrange within a day or two after launch.

During the design phase, experimenters should keep recovery accessibility in mind. It is a good idea to create a recovery plan document for the helicopter crew early in the design process in order to avoid overlooking how this aspect will affect accessibility and other issues.

Figure 4-7: Recovery of BEXUS-5

Figure 4-8: Landing position of BEXUS 7

5 TELEMETRY SYSTEMS

The two telemetry systems used are E-Link and EBASS. E-Link is used by experimenters to transfer data to and from ground. EBASS is used by Esrange for piloting and data-taking. EBASS is used only by Esrange unless there are extraordinary requirements from the experimenters.

5.1 E-Link telemetry system

Esrange Airborne Data Link (E-Link) is a telemetry system that offers a simplified use with a standard Ethernet protocol. It is able to handle serial communication but this has to be agreed with the Electronic Supervisor. The system can also handle other types of synchronous and asynchronous user interfaces.

5.1.1 E-Link System Overview

The E-Link system consists of a ground station and an airborne unit. The ground station consists of an antenna, an antenna controller and a Monitor & Control Unit. The airborne system includes the main unit, an antenna, a battery, and an RF interface unit. At least one connection is available to all experimenters.

Use of the RS-232 option is not desired by EuroLaunch.

The main features of the system are:

- A standard and easy-to-use interface for payloads: Ethernet 10/100 Base-T Protocol
- MIL-C-26482-MS3116F-12-10P connectors (as seen in Figure 5-1)
- High data bandwidth, 2 Mbps duplex nominal
- Optional synchronous and asynchronous interfaces
- All electrical parts are approved by FCC and ETSI (standards)
- Fixed IP address allocations

Figure 5-1: E-Link Airborne Unit

5.1.2 Technical Specification of the E-Link Airborne Unit

Antenna:	Vertical polarised omni
Operating frequency:	S-band
Max output power:	Peak 10 watt
Modulation:	DSSS
Channel bandwidth:	Nominal ±11 MHz
Maximum range at LOS:	500 km at 30 km altitude (TBC)
Data bandwidth:	2 Mbps duplex nominal
User interfaces:	2 Ethernet 10/100 Base 3 asynchronous duplex RS-232/422 channels
Power supply:	20 to 38 volt DC
Operation time:	Nominal > 11 hours
Weight:	Nominal ~20 kg, including batteries

5.1.3 Technical Specification of the E-Link Ground Unit

Antenna:	1.8 meter parabolic dish
Operating frequency:	S-band
Max output power:	Peak 10 Watt
Modulation:	DSSS
Channel bandwidth:	Nominal ± 11 MHz
Maximum range at LOS:	500 km at 30 km altitude (TBC)
Data bandwidth:	2 Mbps duplex nominal
User interfaces:	Ethernet 10/100 Base-T – 2 asynchronous RS-232/422 channels – 1 synchronous channel up to 1 Mbps

5.2 Esrange Balloon Service System - EBASS

This system is used by Esrange for piloting of the balloon. Interference must be avoided at all costs.

5.2.1 EBASS Overview

The Esrange Balloon Service System (EBASS) provides functions for:

- Altitude control
- Flight termination
- Load cell controlled emergency termination
- Onboard GPS
- Housekeeping
- Three full duplex, asynchronous, transparent serial connections for payload control and data reception. These are not used for experiments on BEXUS unless there are exceptional circumstances.

Communication between EBASS and the ground station is maintained by a TM/TC-link at the 400 MHz-band.

Figure 5-2: EBASS System with ballast machine to the left

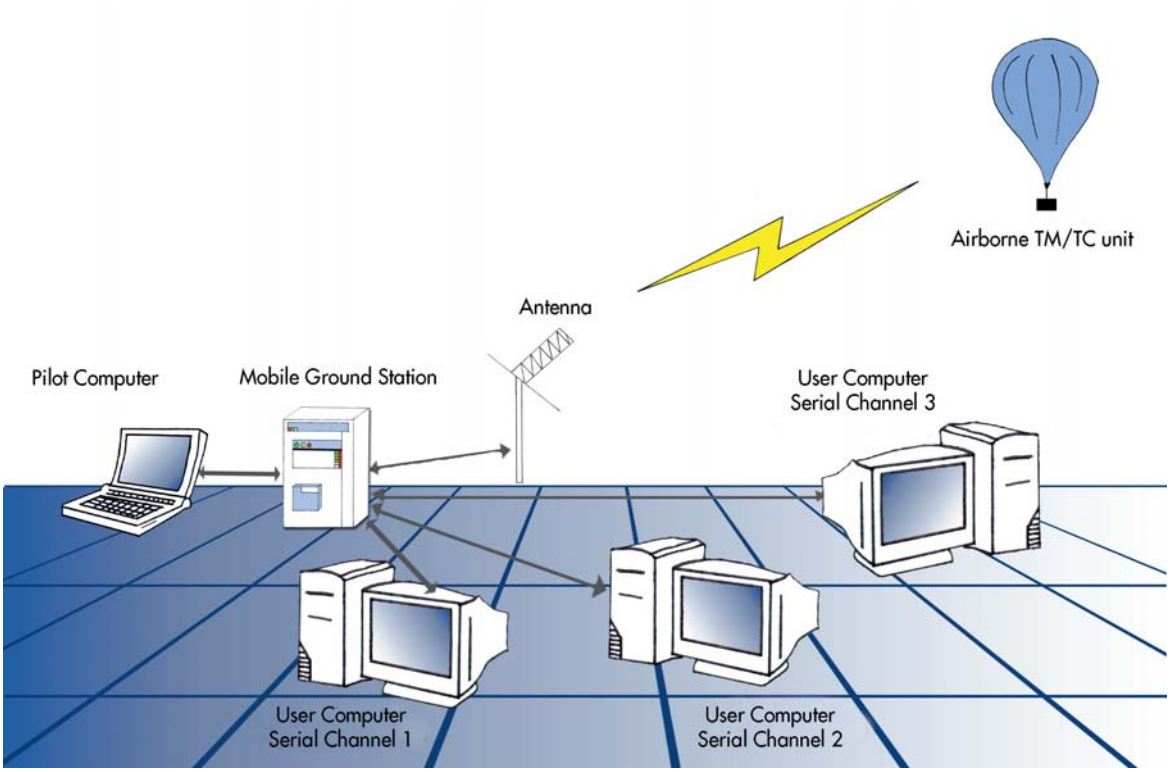

Figure 5-3: EBASS System Overview

Data transmission is available for three payloads simultaneously.

5.2.2 Technical Specification of the EBASS Ground Unit

Transmitting frequency:	449.95 MHz
Modulation:	FM
Total data bandwidth:	38.4 kbps Nominal
Receiving frequency:	402.2 MHz Nominal (400-405 MHz)
Modulation:	FM
Total data bandwidth:	38.4 kbps
IF bandwidth:	50 KHz, 100 KHz 250 KHz and 500 KHz
Output power:	100 Watt
Antenna type:	Helical Antenna
Antenna polarisation:	RHCP
Antenna gain:	12 dBiC
Maximum range:	550 km (at 30-km float & LOS)

Figure 5-4: EBASS Ground System

5.2.3 Technical Specification of the Airborne Unit

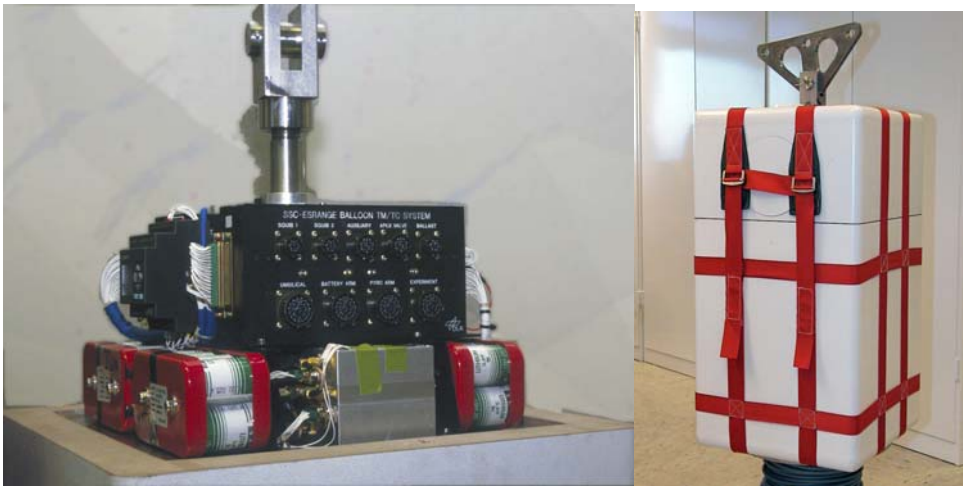

Figure 5-5: EBASS Airborne Unit

Antenna type: Cross Broadband Dipole
Maximum range: 550 km (at 30-km float & LOS)
Transmitting frequency: 402.2 MHz Nominal (400-405 MHz)
Modulation: FM
Total data bandwidth: 38.4 kbps Nominal
Receiving frequency: 449.95 MHz
Modulation: FM
Total data bandwidth: 38.4 kbps Nominal
Output power: 100 Watt
Operation time with maximum battery configuration: 40 hours
Cut down system: Two independent, one is timer controlled
Altitude control: Valve and ballast release

6 DESIGN CONSTRAINTS

6.1 Mechanical design

It is a requirement that the experiment modules are made either gas-tight or equipped with venting holes.

A configuration of an experiment gondola is shown below. At the bottom bulkhead there is a rail with adjustable fixation points to fixate the experiments and other systems.

Distances between the rails are 375 mm in Egon and 370 mm in S-Egon.

See drawing of rails and gondola in Appendix A and more gondola images in Appendix C.

3D CAD Models are available on the REXUS/BEXUS teamsite.

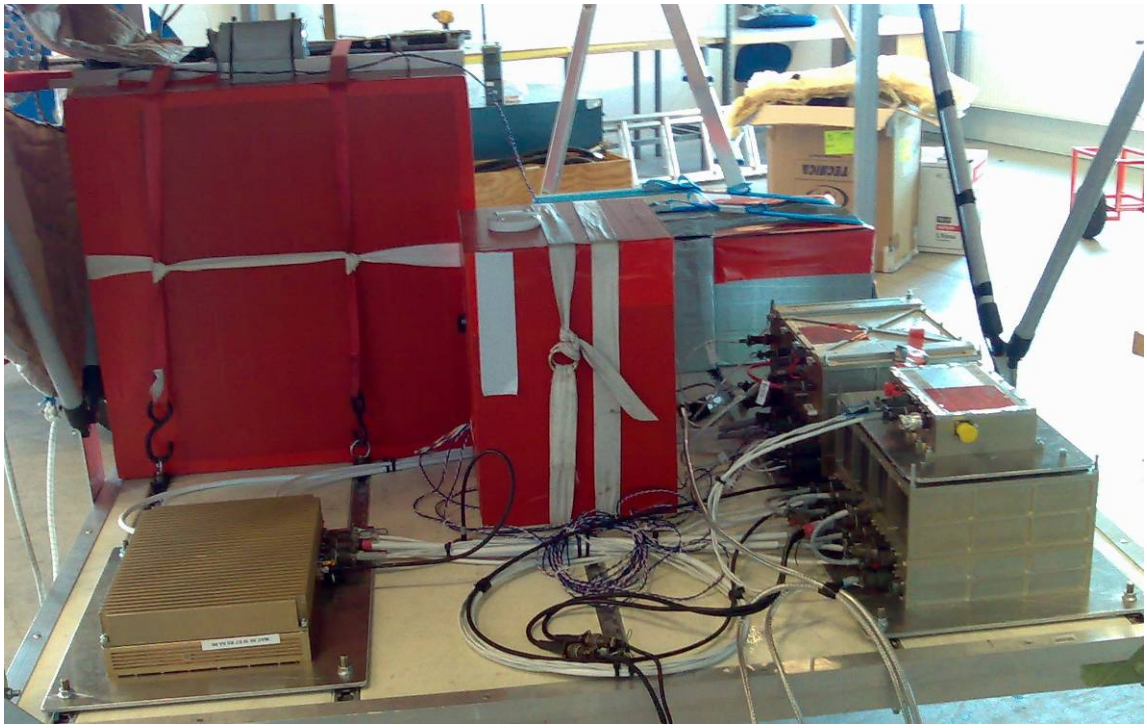

Figure 6-1: Gondola

6.1.1 Experiment mounting

Each experiment must be supplied with a sufficient number of brackets or a bottom plate, in order to facilitate a safe mounting of the experiment. Since there are two different rail CC distances (370 mm & 375 mm), the brackets must have an oval shape in order to make it possible for them to be mounted on both types of gondola. The rails have 1 inch spacing between the mounting holes; this is the same for both gondolas. Two connection methods to the rails are available; bolts and straps. The bolts that can be used to connect to the gondola are 3/8” bolts and connect straight into the mounting holes. As seen in Figure 6-2 below, 3/8-24UNF nuts, wrench size 9/16 (14.3 mm), are used to secure the bolt to the mounting rails, the experiments sit on top of these nuts. The straps have hooks at each end that connect to fixation rings which lock into the mounting holes. Interface between some past experiments and the rails can be seen in Figure 6–1 and Appendix C.

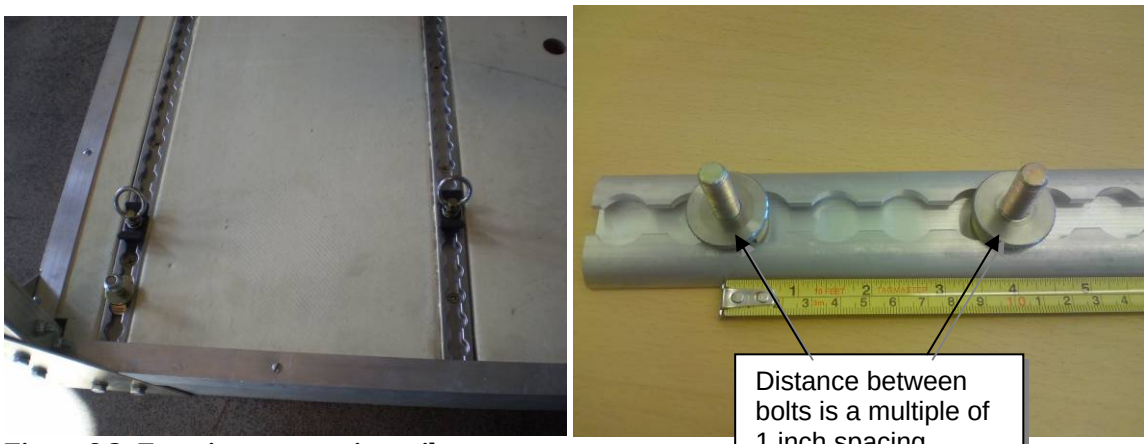

Figure 6-2: Experiment mounting rails

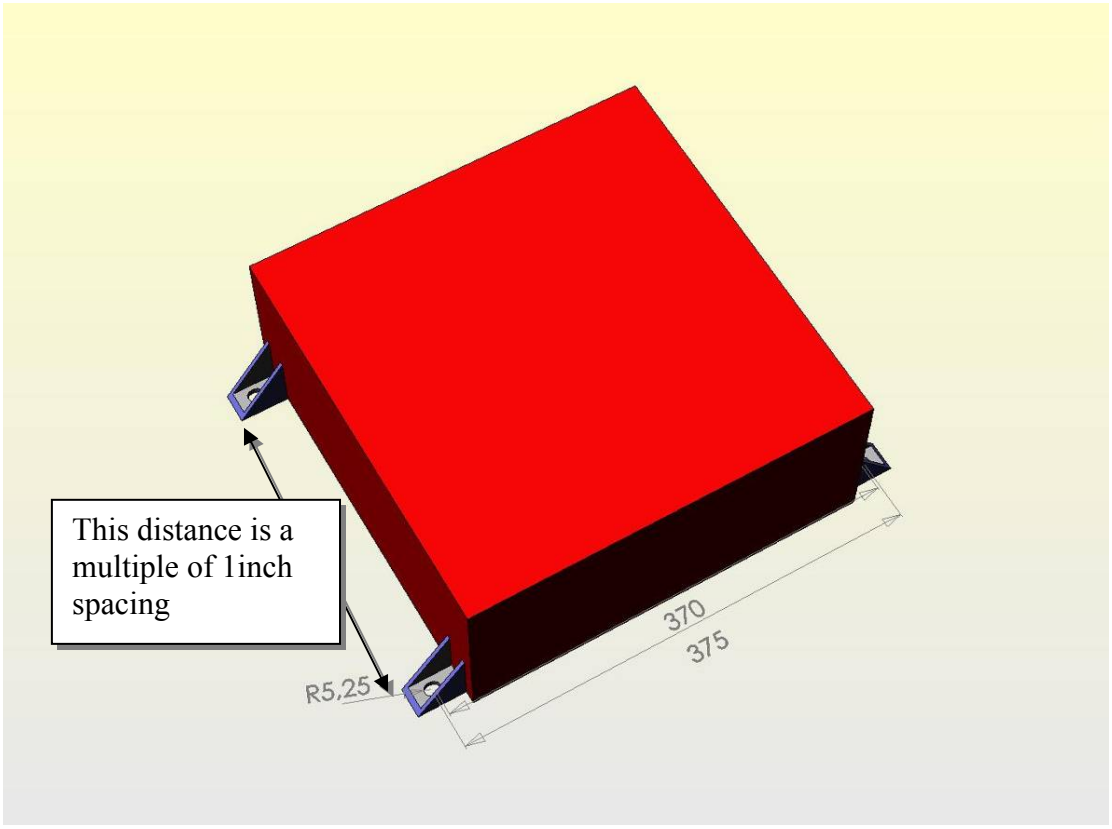

Figure 6-3: Mounting brackets example with critical dimensions

The experiment should be structured to withstand the loads mentioned below, as well as the loads that will be applied during the integration tests. It is the experimenters' responsibility to show that the structure and attachment of an experiment is strong enough. This can be done by stress calculations or load tests. Under no circumstances will there be a flight with an experiment that has a risk of falling off the gondola.

6.1.2 Acceleration

The design load used for the payload is: - 10 g vertically and +/- 5 g horizontally.

6.2 Electric power

A 28V/1A (1300 mA hrs) battery power will be supplied to each experiment if needed. The experiment must have a 4 Pin connector type MIL – C-26482P series 1, placed on the outside of the structure / housing.

Pin A: +

Pin B: - , do not connect to chassis or ground

If the experimenter chooses to use some other electrical system or batteries, it has to be discussed with the BEXUS project manager before the critical design review (CDR).

6.3 Interface Description for E-Link Experiment Channels

6.3.1 Front panel connector (E-Link side)

The E-link is a fully transparent connection between the ground based local user and the experiment. This wireless data link can be used for bi-directional purposes the same way as an LAN network connection with the experiment. A RJ45 connection will be supplied by SSC for between the experiment and the E-link system.

6.3.2 Cable mating connector (Experiment side)

A panel mounted connector for the E-link will be supplied by SSC. This connector (Amphenol RJF21B) can be mounted to the front or side panel of the experiment. The inside of the connector requires a standard RJ45 (Ethernet) connector. Connector and drilling pattern are depicted below.

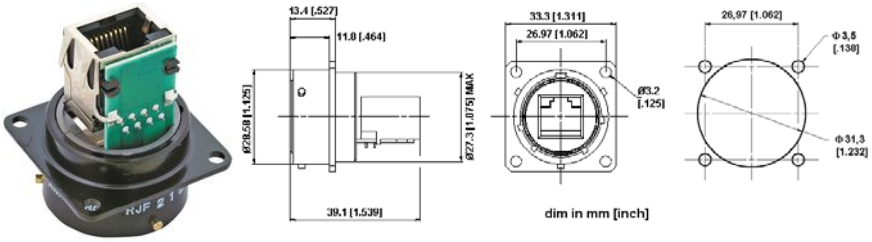

Figure 6-4: drilling pattern for the RJF21B connector (source: http://datasheet.octopart.com/RJF21B-Amphenol-datasheet-11361.pdf)

6.4 Thermal Environment

6.4.1 Pre-Launch Phase

In normal conditions, the preparation of the payload is done at a room temperature of approximately 20±5°C.

After preparation, the payload is transported to the launch pad. The ambient temperature during the transport can be low (down to -15°C), depending on the outdoor temperature, and the exposure time can be up to several hours.

6.4.2 Count Down Phase

Experience shows that during count down, the experiment modules tend to see an increase in temperature over time, especially if long holds are required. Some actions can be taken at the launch pad to improve the situation, however it is recommended that heat sensitive experiment modules, or experiment modules that create high temperatures within the gondola, should include temperature regulation in the experiment design.

6.4.3 Flight phase

The thermal environment of the flight may see temperatures down to -90°C.

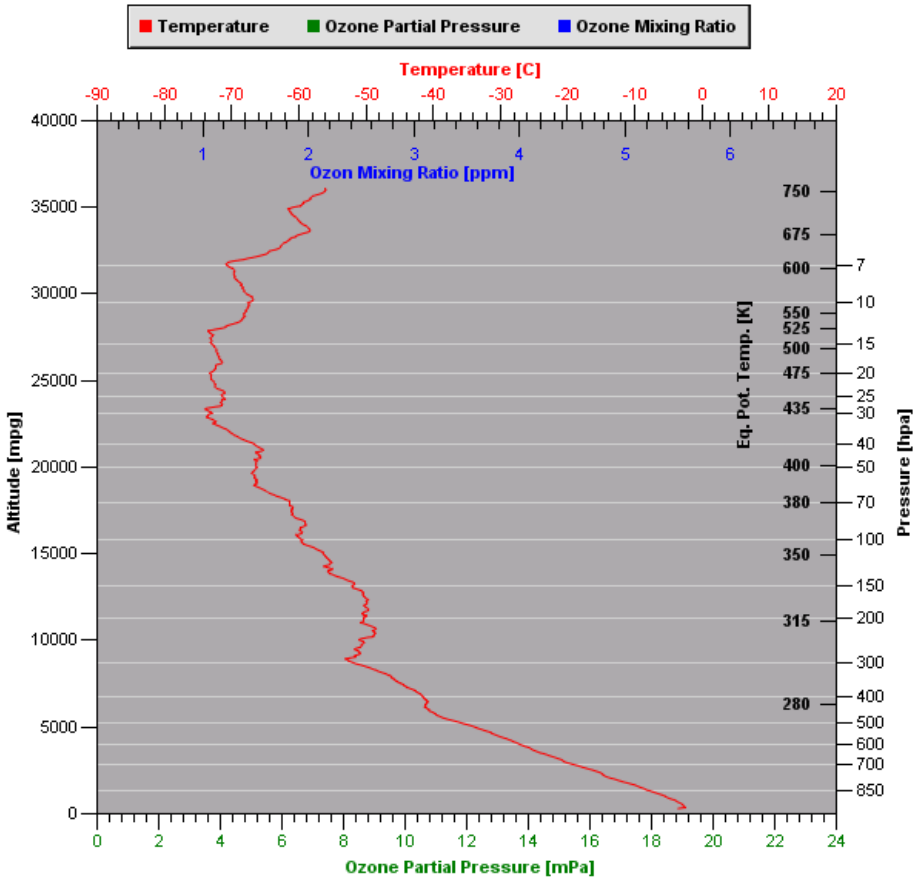

Figure 6-5: Temperature graph from 2004-10-18 (Ozone sondes are available, but not normally flown with BEXUS)

6.4.4 Post-flight phase

After the impact, the payload will most likely be subjected to snow and cold air in the impact area for a period of typically one to two days. The temperature during the season when BEXUS is launched is normally between 0°C and -15°C. Experiments sensitive to low temperatures must be designed for these post flight conditions.

6.5 Radio frequency constraints

In general, for every transmitter that will be used at SSC/Esrange during a campaign, information must be given to Esrange well in advance, in order to receive permission to transmit RF.

At Esrange, the reception of weak satellite signals might be jammed and special care must therefore be taken regarding when and how RF transmitting occurs.

It is also necessary to apply for frequency permission at the PTS (Swedish Post and Telecom agency). SSC/Esrange can either apply on behalf of experimenters or give the information needed to perform such applications. The information required in advance includes parameters such as transmitting frequency, radiated power, bandwidth of signal, antenna, antenna pattern, and modulation type.

The following frequencies are used in safety, telemetry, and recovery systems and are therefore not allowed for use by any experiment:

Table 6-1: Frequencies that are not allowed for use by any experiment

400-405 MHz
449-451 MHz
1025-1035 MHz
1089-1091 MHz
Ch 2-14 in 2.4 GHz-band

6.6 Durability

6.6.1 Power

During the pre-flight tests and the count down, the experiments will be turned on and off several times. Make sure that there is enough battery, memory, etc. to survive these activities, in addition to that which is required for the flight. When considering the power budget, the possible wait times when the experiment is turned on but can not be accessed should be taken into account (most commonly testing and launch attempts). Be prepared to have power supplies for 6 hours of testing, sometimes it is possible to use external power supplies for these but not always, this must be arranged with EuroLaunch by the CDR stage. The launch attempts can last 6 hours or more before the launch. Be prepared for possible aborted launch attempts as it is not uncommon to go through a countdown 2 or 3 times before a launch is achieved. The experiment must either have a single power supply that can last through all of this, use a rechargeable system, have spare battery packs, use cold fusion or take advantage of a perpetual motion machine.

6.6.2 Hercules impact

Although relatively rare, for experiments that protrude from the gondola, it should be considered that an impact with the Hercules during the launch is a possibility. Location on the gondola, housings and materials can be selected to minimize a component failure in the case of a collision.

6.6.3 Landing considerations

Due to the unpredictable nature of the gondolas' landings, the experimenter should be prepared for a wide range of possible environmental influences. Submersion of the experiments in water is possible, if this will be an issue for the experimenters, precautions should be taken. During the landing, organic matter and soil may become lodged in the experiments, especially if they protrude beyond the gondola.

If the experiment protrudes beyond the gondola, sacrificial joints (or other contingency plans) should be considered if it is foreseen that an impact could damage the experiment seriously.

6.7 Recommended Tests for Experimenters

6.7.1 Vacuum test

This test is applicable not only for experiments which will take place under vacuum conditions, but also helps to verify that systems, mainly electrical, have nominal performance in the absence of convective cooling. It is the responsibility of the experimenter to perform this test, if necessary.

Basic Procedure

- The experiment shall be integrated and placed in a vacuum chamber (pressure below 0.5 mbar).
- Experiment data shall be supervised and recorded during the test.
- The experiment shall be operating during the lowering of the pressure in the vacuum chamber. The experiment shall be in a similar mode as during the real BEXUS flight.
- After this functional test / flight sequence has been performed, it is recommended that the module is kept operating for an additional 15 minutes, in order to detect any leakages or overheating problems.

6.7.2 Thermal test

A thermal test is mainly performed in order to verify a nominal function of the experiment during the worst-case temperatures that can be experienced during count down and launch. It is the responsibility of the experimenter to perform this test, if necessary. The heating of the outer structure/gondola is normally not included or tested.

Basic Procedure

- The experiment shall be integrated and placed in a thermal chamber.
- Experiment data shall be supervised and recorded during the test.
- The temperature shall preferably be measured in several places in the experiment.
- **Low temperature test:**
  Regulate the temperature in the thermal chamber, preferably down to – 80°C but at least to - 40°C. When the measured temperatures in the experiment have stabilised, perform a functional test / flight sequence. Be aware of condensation problems if the test is performed in normal humidity.

6.7.3 Mechanical Test

Mechanical tests are necessary to ensure performance of the experiment during flight after possible shocks that occur during launch. If not, it is possible that the balloon will be launched with the experiment non-operational. There are two major risks to be identified, structural integrity and experiment durability. It is the responsibility of the experimenter to perform this test, if necessary.

Basic Procedure 1

- The experiment should be placed on a solid surface with a clear area around the test area.

- The experiment should then be loaded with between 10 and 30 times the experiment's own weight (depending on the structural design) in a stable and secure manner.

Basic Procedure 2

- An area should be cleared in which the experiment can be safely dropped (the persons carrying out the procedure should be wearing a sufficient level of safety gear).
- The experiment should be dropped from a height of 1-3 metres onto a solid surface.
- Afterwards, the experiment should be checked for full functionality by system tests but a visual check is also important to see if any cabling or mechanisms have been affected.

6.7.4 Bench Test

All experiments should carry out a bench test of their experiment before transport. The test should be carried out for a maximum duration mission (6 hours wait before launch, 6 hour flight and possibly a wait time before recovery when appropriate). This test should be carried out as there are many issues which arise only after long duration of operation. Where possible, this is best done using the same power system as for flight (with voltage and temperature monitoring of the batteries). Possible issues that have occurred in the past is microcontroller malfunction with low power and battery rupture due to overdrawn current. The experiment should be supervised at all times in case of a battery failure. It is the responsibility of the experimenter to perform this test, if necessary.

Basic Procedure

- The experiment should be assembled as for flight in a safe area removed from interference (both environmental and human).
- Monitoring of temperature and voltages for critical electronic components should be set up where desired.
- The experiment should be run through a simulated countdown for a total of 6 hours (including ethernet connection and wait period after switching on). During this period, procedures for interaction with the experiment can also be tested.
- Following simulated launch, the experiment should be run as desired for ascent, float and descent of 6 hours. Here, the possibility of E-Link dropouts should be simulated where appropriate to ensure that correct operation of the experiment will occur when there is no telemetry available.
- Experimenters should also seriously consider running the experiment as they plan for another 24 hours to simulate the wait time on ground before recovery.

6.8 General Design Considerations

6.8.1 Experiment Accessibility

Bear in mind that designing for accessibility will make your task easier throughout the assembly and testing phases. This is an important point that is often overlooked by experimenters. It is in your interest that items such as switches, battery packs and cable connections are easy to access. Considering access to fasteners is also worth the time.

6.8.2 Availability of Parts

A major issue for many experimenters is late delivery and procurement delays. Rather than merely basing a design on parts from catalogues, ensure that they are available, this can save a lot of time and money for experimenters. Avoid designs based on hard to procure items or irreplaceable items where possible.

6.8.3 Experiment Construction Costs

Consider enforcing a three-quote minimum on components where possible (this is often not possible due to the specialized nature of items). When designing, remember that the cost for machining can differ greatly depending on early design decisions. Avoid close tolerances wherever possible, not only is it cheaper but it can save time with assembly. Remember to use experience and judgement; the cheapest items are not always the best selection.

6.8.4 Redundancy

Redundancy is desirable, especially where there are safety or failure risks. It is not as simple for mechanical as electrical but it should be considered during the design process. Redundancy can be simply achieved by separate battery packs, multiple switches, check valves, and other solutions.

6.8.5 Weight and Size Considerations

Minimizing weight is commonly overlooked by experimenters. However, keeping weight low where possible serves multiple functions. For payload organization, when experiments are light and small, it gives EuroLaunch more flexibility in selecting locations for each experiment. It can also result in more experiments being flown. In order to do this, early system design solutions must be generated so that the mechanical engineers can determine the best approaches to minimizing size and weight.

6.8.6 Effectiveness of Testing

When designing your experiment, please take into consideration the testing in the future. This is an issue of accessibility, but also of design. Fast and simple methods of testing, calibrating, or adjusting important items will save experimenters' time. This will also make it simpler for testing carried out by EuroLaunch.

6.8.7 Safety

Safety is of the utmost importance to EuroLaunch. Any experiment that is deemed risky to the public, staff or experimenters will not be flown. Take care to ensure that you perform any simulation, analysis, and testing that will help to convince EuroLaunch that the experiment is safe to fly. If there are any items that you can identify as safety risks, keep them in mind during your design as the possibility exists that the experiment will be removed from the vehicle if it poses a danger.

7 PRE CAMPAIGN ACTIVITIES

7.1 Esrange Safety Board (ESB)

Every campaign or project at Esrange has to be accepted by the Esrange Safety Board. A standard balloon is normally no problem. If there are hazardous items such as chemicals, free-falling objects, lasers, radiation, etc. included in the experiments, there may be a need for further investigation. This may take some time and should be done early in the design process, well ahead of the start of the campaign.

7.2 Flight Requirements Plan (FRP)

The BEXUS Project Manager provides Esrange Space Center, as well as all parties involved in the project, with the Flight Requirements Plan. This document gives a complete description of the specific project, including payload information, a list of hazardous materials, experiment requirements on the launch operations, tools required, participants expected, etc. This is an important document used to inform all participants in the campaign.

The first version of the FRP will be distributed after the PDR (training week). Inputs are requested from every experiment team, regarding interfaces, telemetry, power consumption and special experiment requirements.

7.3 Payload Assembly and Integration

The payload integration tests are performed at EuroLaunch premises and/or premises leased by EuroLaunch. Nominally, these tests start two weeks before the planned start of the launch campaign.

7.3.1 Experiment Incoming Inspection

All experiment mechanical and electrical interfaces will be inspected upon delivery to the payload assembly and integration premises.

8 CAMPAIGN ACTIVITIES BEFORE START OF COUNT DOWN

8.1 Description of Esrange Space Center

All the necessary information for a user of Esrange can be found at:
www.ssc.se under 'Launch Services'.

Its main content is:

- Range description (capabilities, layout, environment...)
- Range administration (communications, accommodation, freight, supplies...)
- Safety regulations
- Instrumentation (telemetry, tracking, observation, scientific...)
- Operations (assembly, checkout, flight control, recovery, requirements, procedures)
- Satellite facilities

8.2 Safety

Safety always comes first at Esrange. Before the start of a campaign, a safety briefing will be held. It is mandatory for all visiting personnel to attend this briefing.

8.2.1 Additional Esrange Safety Board meetings

If a safety issues arise during a campaign, there might be a need for extra Safety Board meetings before a launch is possible.

8.3 Time schedule

The BEXUS launch campaign takes place over approximately 7 days. This does not allow any time for errors or delays and it is important to be well prepared.

The first two days are used for preparations and the next five for possible launches.

Every morning, there is a status meeting in one of the conference rooms, where the upcoming activities are discussed.

8.3.1 Overview of build-up schedule

A more detailed schedule will be issued closer to the campaign week. Depending on how the preparation work progresses and the weather forecasts, there might be changes during the campaign week itself.

Action	Date
Start of campaign Safety briefing and general information	Day 1
Preparation of Experiment and Service Systems	Day 1–2
RF interference Tests Flight Readiness Review Pre-flight meeting	Day 2
Daily briefings and possible launches	Day 3–7
Evaluation of data Post flight meeting Cleaning of workplaces Campaign dinner	Day 7

Figure 8-8-1: Schedule overview

8.4 Planning

Experiment teams are strongly advised to think through all aspects of the experiment, the build-up, all tests, the launch and the flight phase. With this input, make a detailed plan of how to work, who is doing what (team member, Esrange staff, etc.) and how much time is needed to do all this.

A checklist is the key item to success: even the smallest thing, such as flipping a switch, should be in the list.

Without good build-up plans and checklists there is a significant risk of failures and delays during the campaign week. All of this should be documented in the SED.

8.5 Assembly of balloons and payloads

8.5.1 Assembly of balloons

All assembly and preparation activities related to the balloon and its subsystems are the responsibility of the EuroLaunch team. This is normally done in the Basilica building.

8.5.2 Assembly and checkout of payloads

Payload assembly and preparations are conducted by the BEXUS Project Manager together with EuroLaunch staff and the experiment teams. A dedicated person will be assigned to each gondola. Working space in the launching area will be allocated to each team, normally in the Cathedral building.

Figure 8-2: From left to right: the Chapel, Cathedral and Basilica preparation & assembly buildings

8.5.3 Equipment

There is one soldering station located in the Cathedral assembly hall. There is also basic measurement equipment and toolboxes available to borrow.

If you need some special tools or equipment, be sure to either bring it with you, or specifically state that you need it when you give input to the Flight Requirements Plan.

Figure 8-3: Standard Equipment Set at Esrange

8.6 Flight Simulation Test (FST)

When all experiments are operating nominally and there is enough time for this test, a simulated count down and flight sequence is performed. All telemetry and telecommand signals will be recorded in the telemetry ground station, during the test.

It is important that the any changes/modifications made to H/W or S/W after the Flight Simulation Test are restricted to a minimum. Non-conformances discovered during the test can of course be corrected, but care must be taken to verify that no further malfunctions are induced by the correction.

Basic Procedure

- The experiment shall be integrated and in flight configuration. The telemetry and telecommand checkout system or simulator shall be connected via the interface harness.
- Experiment data shall be supervised and recorded during the test.
- A nominal realistic count down and flight procedure shall be followed.

8.7 RF interference test

When all experiments are installed in the gondola, a RF interference test is conducted. The gondola is picked up by the launch vehicle and placed together with all other transmitting / electrical hardware at the same distances as in a real flight. A test with all electronic equipment as well as experiments operating in flight mode is then performed. If an experiment is causing interference with EBASS or E-Link it will not be granted permission to fly. If there is interference between two experiments, the problem will be discussed and a solution or compromise will be found. After the RF test, the gondola is sealed and there are no further changes possible to any experiment. During count down there are very limited possibilities to fix any problem. If there is no quick fix available, the experiment may have to fly with limited functionality or in switched-off mode.

8.8 Flight Readiness Review (FRR)

The Flight Readiness Review (FRR) is conducted by the EuroLaunch coordinator of the launch campaign, after successful completion of the RF test and ground support stations checkout.

The purpose of the FRR is to authorise start of the count down phase

In order to do this it is necessary:

- to ensure that all experiments are ready for the flight. For this, each appointed experiment module manager (team leader) shall give a status report at the meeting. In addition, the PI is requested to state the operative status of the experiment
- to ensure that all ground and payload service systems essential for a successful launch, flight and recovery are operating nominally. For this each appointed system responsible shall give a status report at the meeting
- to review the count down list

- to inform all relevant personnel of the safety regulations applicable during the count down phase.
- to inform all relevant personnel of general arrangements implied during the count down phase

8.9 Pre-flight meeting

After a successful FRR meeting there will be a pre-flight meeting. The objective of this meeting is to verify that all flight hardware is ready, Esrange stations are prepared and other flight conditions are in favour of a possible start of count down.

9 CAMPAIGN ACTIVITIES

9.1 Weather constraints

Wind, flight trajectory and visibility are important variables taken into consideration before starting a count down. There is no magic numbers and the decision to start a count down is solely in the hands of Esrange personnel.

Note: It is not possible to guarantee that a launch can take place on one of the 5 days allocated during the campaign week. Plan and prepare so that it is possible for someone else to operate and document the functions of your experiment if the launch is postponed to a later opportunity. This should be documented in the SED.

9.2 Balloon launch conditions

Launch period:	September / October
Launch window:	05.00 – 20.00 LT
Ground wind:	less than 4 m/s.
Vertical visibility:	more than 75 m

Conditions should be sufficient for helicopter recovery on the same day for a short flight or on the next day for other cases.

9.3 Safety on the balloon pad

Esrange has the overall responsibility for safety and has the Veto right in all safety issues during all activities within the Esrange base area. In the case of clients / guests with stronger safety rules then those of Esrange, the stronger rules will apply.

No one is allowed on the pad during count down without the permission of the Operations Officer.

There are several heavy vehicles with limited visibility moving on the pad. To be visible to the drivers, Esrange provides participants with fluorescent safety vests. It is mandatory to wear these when entering the launch pad

When E-link is in a high-power-transmitting mode there is a 10 meter safety distance around the gondola. This is marked with cones.

In the final 30 minutes before launch there is no more access to the experiments.

At launch, everyone must stand close to the balloon pad buildings. If the ascent trajectory is towards the buildings, all persons must go inside the buildings and remain there until instructed otherwise.

9.4 Personnel during the launch

9.4.1 Esrange Project Manager

This person acts as an interface between the guests and Esrange personnel. All requirements must be sent to him before the campaign, so that he can compile the Flight Requirements Plan. It is important that he has all information as early as possible in order to avoid delays during the campaign week.

9.4.2 Payload Manager

This person acts as the contact point for the experimenters during the count down. He relays questions between the experimenters and the Operations Officer, via WT or telephone. He also informs the Operations Officer about status of the Gondola and the experiments and informs him when the PL is ready for pick up.
The Payload Manager communicates with the Electronic Supervisor and the electronic team regarding the E-Link telemetry issues. Finally, he is responsible for keeping experimenters and guests at the necessary safe distances during pick up and launch.

9.4.3 Operations Officer

The Operations Officer handles the count down and is the focal point for all activities.

9.4.4 Launch Officer

The Launch Officer handles all personnel and equipment related to the launch. He is also responsible for safety on the launch pad.

9.4.5 Safety Officer

The safety for third parties is the concern of the Safety Officer. He authorises the Balloon Pilot to send commands to end the flight.

9.4.6 Electronic Supervisor

Handles all issues related to EBASS, E-Link and the RF interference test.

9.4.7 Esrange Telemetry Station (ETM)

The Esrange Telemetry Station (ETM) handles the receiving, transmitting and recording equipment during preparations and launch.

9.4.8 Balloon Pilot

The Balloon Pilot handles the balloon piloting system and monitors the housekeeping data.

9.5 Count down and launch

During the count down phase, important count down information is displayed on 'PA video monitors' at various locations around the launch site.

The nominal lift off time is planned for between 0500 and 2000 LT. The launch window is determined by the payload preparation time, hold requirements and the time of daylight.

The decision to start the count down is taken at a weather briefing immediately before the planned start of count down. This decision is based on dedicated weather forecasts, as well as wind data obtained by a meteorological balloon released from Esrange some minutes beforehand. If the weather conditions are unsuitable for launching the vehicle, the launch will be delayed until the flight conditions are fulfilled.

The general launch procedure may be subject to changes. Be sure to design your experiment so it can handle not only the flight but also 3 hours of CD (on internal batteries if used) plus some possible holds (it is possible that the CD including holds will last for 6 hours or more).

Experiment teams' ground equipment will be situated in the Cathedral building; transparent communication with the experiment is provided via a switch.

The schedule below indicates the standard count down actions relative to launch (T = 0). A final version of these actions is issued at the pre-flight meeting.

Time (h:min)	**Action**
T – 3:30	Decision meeting.
T – 3:25	Start pad preparations.
	Start beacon & transponder tests.
T – 3:00	Start E-Link tests.
	Start BEXUS preparation.
T – 1:50	Start check of EBASS equipment.
T – 1:10	BEXUS payload tests completed. Go from experimenters.
T – 1:08	OK from EBASS and E-Link for unfolding of balloon.
T – 0:40	Latest accesses to experiments.
T – 0:30	Start of balloon inflation.
T = 0	Lift off.
T + ~4:00	Command cut down followed by recovery.

9.6 Radio discipline

Please observe the following regarding radio communication:

- Use functional names, avoid personal names
- Use basic English
- Spell by analogy if necessary
- Use 'pro-words' below to minimize the risk of mis-readings
- No horse play or bad language
- Minimize all radio traffic from -5M until +1M

Table 9-1: Radio pro-words and meaning

Pro words	**Meaning**
Affirmative	YES
Negative	NO
Active	Work commanded is in progress, completion will be reported
Break – Break	I must interrupt this conversation because of an urgent message.
Correction	You have made a mistake. You should have said (or performed) or, I have made a mistake; I should have said
Disregard	Disregard what I have just said. It is not applicable or is in error
Execute	Carry out the instruction
Go ahead	I am on the net. Proceed with your transmission
I say again	I am repeating the message for clarity
Out	I have completed this conversation
Proceed	Go ahead with your task
I copy	I received your last message satisfactorily and understand
I copy, Wilco	I have received your message, understand it, and will comply
Say again	Repeat your last communication
Speak slower	You are talking too fast
Standby	I must pause for time or wait a few moments
Verify	Check status or correctness
Roger	Acknowledge your transmission

Table 9-2: Call sign during pad preparation

Functional names	Function in the balloon processes
Operation	Operations Officer
Launch Officer	Launch Officer on balloon pad
Electronics	Electronic responsible person at launch pad (for EBASS, E-Link)
Assistant Electronics	Assistant electronic responsible at launch pad (for EBASS, E-Link)
Safety	Safety Officer
TM	Telemetry station
Pilot	Balloon Pilot
Scientist	Scientist / experimenter responsible
Payload	Payload Manager

9.7 Deliverables (data)

EuroLaunch will add this information when available.

9.8 During the flight

As soon as the balloon is in a steady ascent, the Balloon Pilot and Operations Officer will move to the Operations Office in the main building. The flight will then be monitored by the Balloon Pilot and the Safety Officer.

9.9 Recovery

The helicopter is equipped with tracking receivers for the payload beacon signal, and can also be equipped with a payload TM receiver for data reception of the payload's GPS position.

During the flight, the payload trajectory will be tracked by means of the transmitted GPS-data in the TM ground stations.

During the descent of the payload, the prediction on the impact point co-ordinates is reported to the helicopter from Esrange. The helicopter starts their operation to locate the payload after the impact. At the impact site, the helicopter crew disassembles the flight train for transport by truck back to Esrange. Your experiment will then be exposed to vibration, shock loads and the hostile environment on the back of the truck.

The whole operation is normally completed within two days after launch.

9.10 Post Flight Meeting

After the recovery, a Post Flight Meeting is held to debrief the flight and a short flight performance report is stated. A short presentation of the performance of each experiment is requested.

10 EXPERIMENT QUALITY ASSURANCE

The major concerns of EuroLaunch related to Quality Assurance (QA) on the experiment level are that the experiment shall fulfil the interface requirements and that the module can fly in a BEXUS payload without jeopardising the performance of the other systems or experiments. In addition, EuroLaunch has a strong concern that the experiments shall perform nominally.

The following advice reflects this concern.

10.1 Materials

In addition to normal concerns when choosing materials, special attention shall be paid to out gassing phenomena due to vacuum environment during flight.

As an aid the ECSS-Q-70-71 [6] (*Data for selection of space materials and processes*) may be used.

10.2 Components

All electrical and mechanical components must have a reliability that is consistent with the overall reliability of the payload. For electronic components, MIL-std specified types are recommended.

10.3 Additional quality topics

In addition to the QA-topics above, the following topics shall be treated if required by EuroLaunch:

- Procured products and audits

  Careful planning of the procurement and manufacturing must be made for identification of long lead items. Preferably, a flow chart shall be made which shows the sequence of operations.

- Manufacturing control and inspection

  For the manufacturing and inspection of critical processes, the personnel should be aware of standards in applicable areas, such as:

  - Manual soldering according to ECSS-Q-ST-70-08C
  - Crimping of connections according to ECSS-Q-ST-70-26C

  Specific requirements of the project or product concerning cleanliness, contamination and environment shall be stated in the input to the Flight Requirements Plan.

  When positioning the parts or components, the sensitivity to, heating, ESD and electrical disturbances shall be considered.

  Connectors shall be well marked and preferably keyed.

- Re-used item

It is important to consider the complete history of the re-used item, by consulting the hardware logbook or former project log-book; to be sure that it does not include any hidden failures.

- Availability and maintainability

  Spare parts for components susceptible of failure, shall be available during the payload AIT and the launch campaign. The design shall allow for easy and fast replacements of such components.

- Handling, storage, and packing

  ESD susceptible components shall be handled in an ESD protected environment.

  Before transport, the product shall be thoroughly packed to withstand the expected loads. The use of a bump recorder is recommended.

10.4 Personnel Safety

The BEXUS experiments and dedicated equipment must fulfil safety requirements according to Swedish law. The Swedish Work Environment Act is a general act that is backed up by special laws and regulations in different fields. The Swedish work environment authority issues these regulations.

Special provisions apply (among others) to the following fields:

Explosives
Inflammable material
Chemical hazards
Electrical facilities
Radiological work

All the above mentioned laws and regulations are available at:
http://www.av.se/inenglish/lawandjustice/workact

The experimenter shall state that the module fulfils the applicable requirements and establish a list of hazardous materials, which shall be communicated to EuroLaunch no later than the MTR. This information shall always accompany the experiment.

10.5 Safety at Esrange Space Center

The Safety Regulations that apply at Esrange may be found in the Esrange Space Center Safety Manual [Ref 4]. It is a requirement that all personnel participating in the campaign shall have read the safety regulation in [Ref 5] prior to their arrival at Esrange Space Center. Each team leader will have to sign a document to verify that all team members have been provided with a copy of the safety manual. See Appendix B.

11 COORDINATE SYSTEM DEFINITION

This chapter will give a short overview on the coordinate systems that are used for the BEXUS onboard sensors, GPS and tracking systems. Knowledge about the coordinate definition and transformations is important for the analysis of sensor data during the flight and for the post flight analysis. The following table lists the used coordinate systems.

Table 11-1 Coordinate Systems

ECEF	Earth Centered, Earth Fixed
EGS84	World Geodetic System 1984
LTC	Local Tangent Coordinate System

The global reference system **World Geodetic System 1984** (WGS84) is used for the BEXUS GPS position data. This system is based on the ECEF system. The Local Tangent Coordinate System (LTC) is important for observation of the vehicle from Launcher, Tracking or Radar Station. Details are described in Ref [9].

11.1 Earth Centered, Earth Fixed (ECEF)

If a geocentric coordinate system rotates with the Earth, it results in **Earth-Centered Earth-Fixed Coordinate System**, abbreviated as **ECEF**. The main difference with this system is that the primary axis is always aligned with a particular meridian. The x_{ECEF}-Axis points toward the Greenwich-Meridian which is defined as longitude 0°. This coordinate system rotates with the Earth with the primary axis x always through the Greenwich Meridian.

The position of an object is defined with the geocentric Latitude φ_{gc}, which is measured positive North of the equator, the Longitude θ, which is measured positive towards East from the Greenwich Meridian and the distance d from the Earth center.

$$\vec{r}_{ECEF} = \begin{pmatrix} x_{ECEF} \\ y_{ECEF} \\ z_{ECEF} \end{pmatrix} = d \cdot \begin{pmatrix} \cos\varphi_{gc} \cdot \cos\theta \\ \cos\varphi_{gc} \cdot \sin\theta \\ \sin\varphi_{gc} \end{pmatrix} \qquad \text{Eq. 10-1}$$

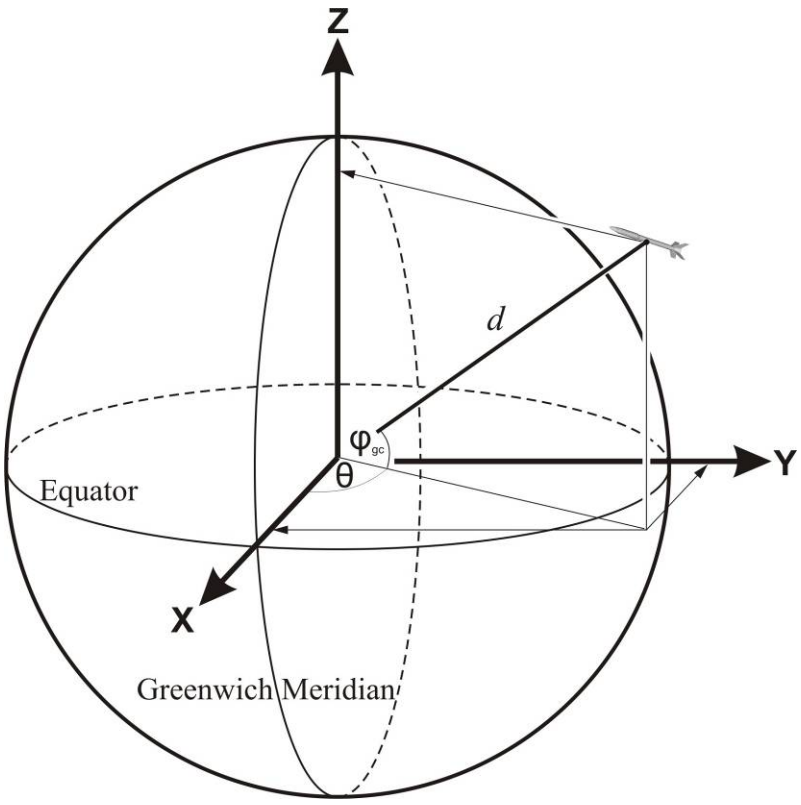

Figure 11-1: ECEF Coordinate System

The reference ellipsoid is rotation-symmetric and every plane cuts the ellipsoid to an ellipse with the flattening $f_{\oplus}$, which is defined with the relative difference of the equator and pole radius.

$$f_{\oplus} = \frac{R_{\oplus} - R_{Pole}}{R_{\oplus}} \qquad \text{Eq. 10-2}$$

The WGS84 Ellipsoid has a flattening of $f_{\oplus} = 1/298.257223563$ and the equator radius, $R_{\oplus,}$ is 6378137 m [Ref [9]]. The Earth eccentricity, $e_{\oplus,}$ can be calculated with following equation.

$$e_{\oplus} = \sqrt{1-(1-f_{\oplus})^2} \qquad \text{Eq. 10-3}$$

The position of the vehicle is given in geodetic coordinates relative to the reference ellipsoid. The geodetic longitude θ corresponds to the geocentric longitude. Not like the geocentric latitude, φ_{gc}, which is the inclination of the position vector to the equatorial plane, the geodetic latitude, $\varphi_{gd,}$ describes the angle between equatorial plane and the normal to the reference ellipsoid. It is positive to the North and negative to the South.

The difference of geodetic and geocentric latitude is shown in the following figure:

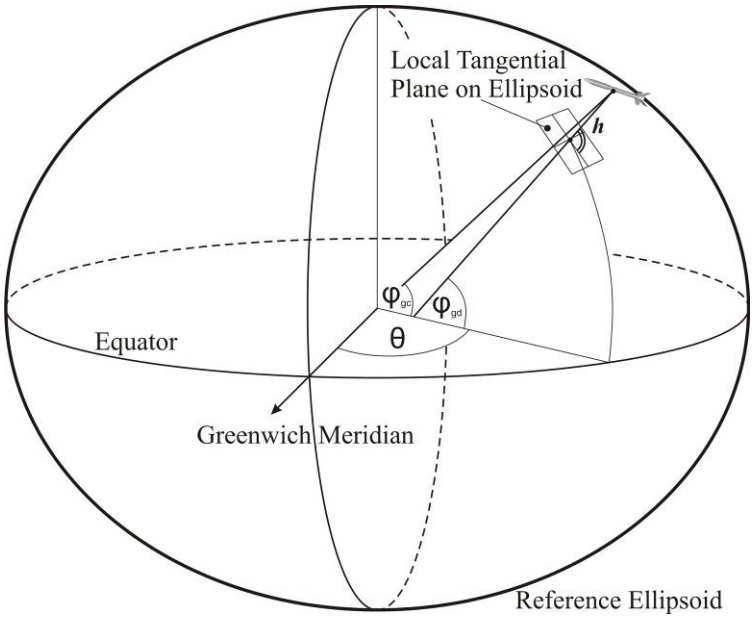

Figure 10-2: WGS84 Reference Ellipsoid

The flattening of the Earth is very small because the difference between the Earth radius at the equator and the poles is less than 22 km. Therefore the difference between geodetic and geocentric latitude is 12 arcminutes.

11.2 Local Tangential Coordinate System (LTC)

The **LTC system** rotates with the Earth. The E axis points to East, the N-axis points to the North and the Z axis is the zenith that is perpendicular to the tangential plane at the observation location (usually Launcher). This location is defined by the geodetic latitude φ_{gd} and geodetic longitude θ.

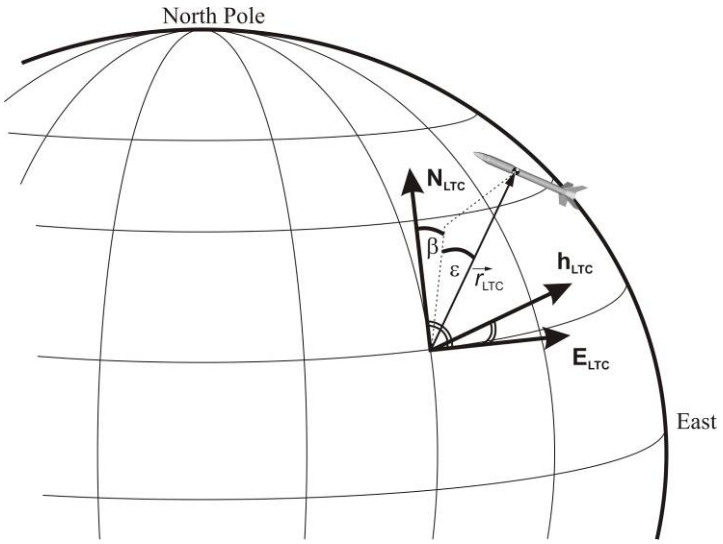

Figure 10-3: Local Tangent Coordinate System (LTC)

Two observation angles define the position of the vehicle from the observation location. The azimuth β is measured clockwise around the observation location starting at North. It varies between 0° and 360° and is calculated with following equation:

$$\beta = \arctan\left(\frac{east_{LTC}}{north_{LTC}}\right) \qquad \text{Eq. 10-4}$$

The **Elevation,** ε, is measured between the horizon and the vehicle position It varies between -90° and 90° and is calculated with the following equation:

$$\varepsilon = \arctan\left(\frac{h_{LTC}}{\sqrt{east_{LTC}^2 + north_{LTC}^2}}\right) \qquad \text{Eq. 10-5}$$

The transformation between azimuth and elevation to Cartesian LTC-coordinates is done with following equation:

$$\begin{pmatrix} east_{LTC} \\ north_{LTC} \\ h_{LTC} \end{pmatrix} = d \cdot \begin{pmatrix} \sin\beta \cdot \cos\varepsilon \\ \cos\beta \cdot \cos\varepsilon \\ \sin\varepsilon \end{pmatrix} \qquad \text{Eq. 10-6}$$

The distance d between the vehicle and the observation location is also called Slantrange.

APPENDIX A.
GONDOLA DRAWINGS

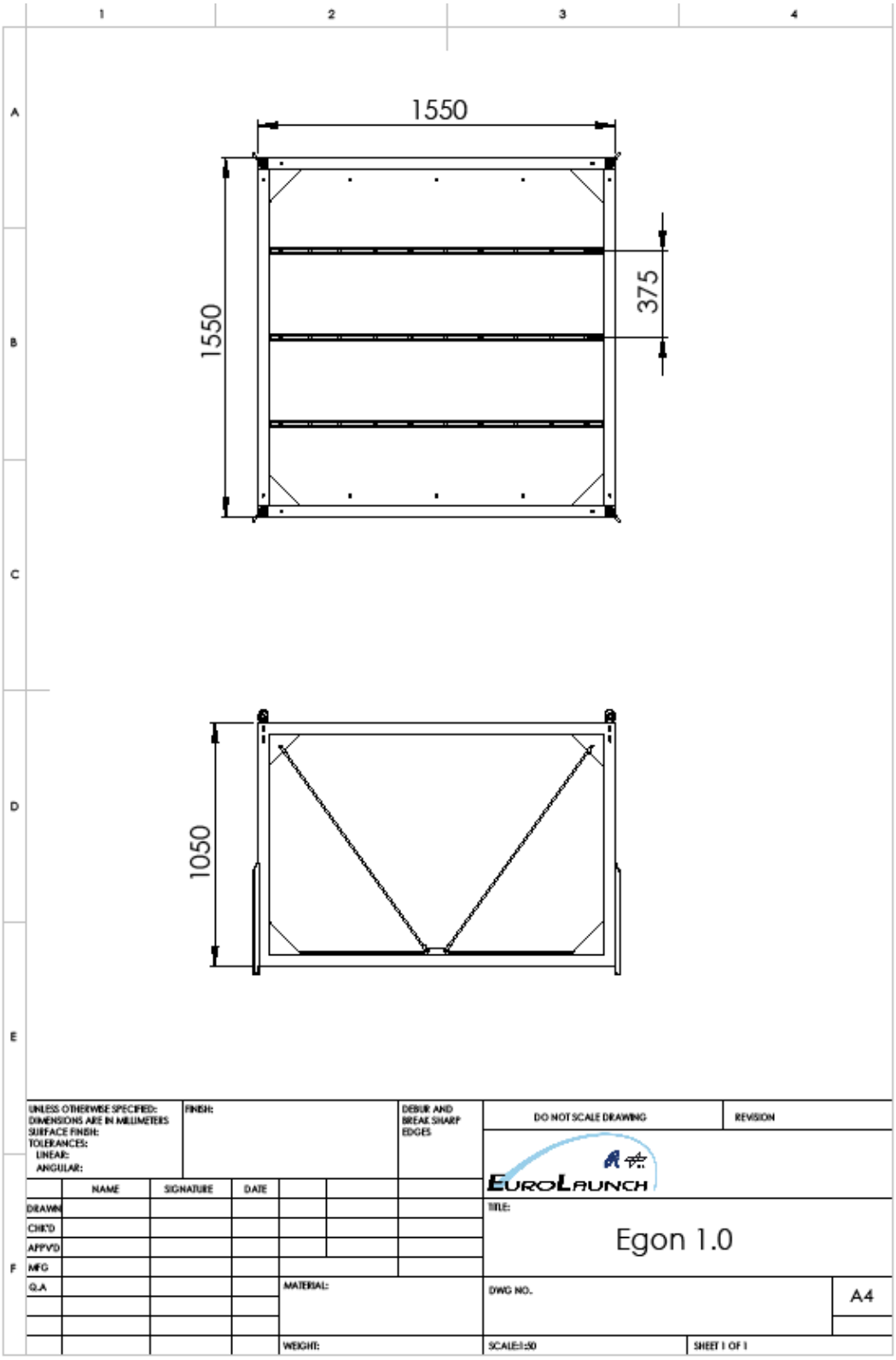

Figure A-1 Egon drawing

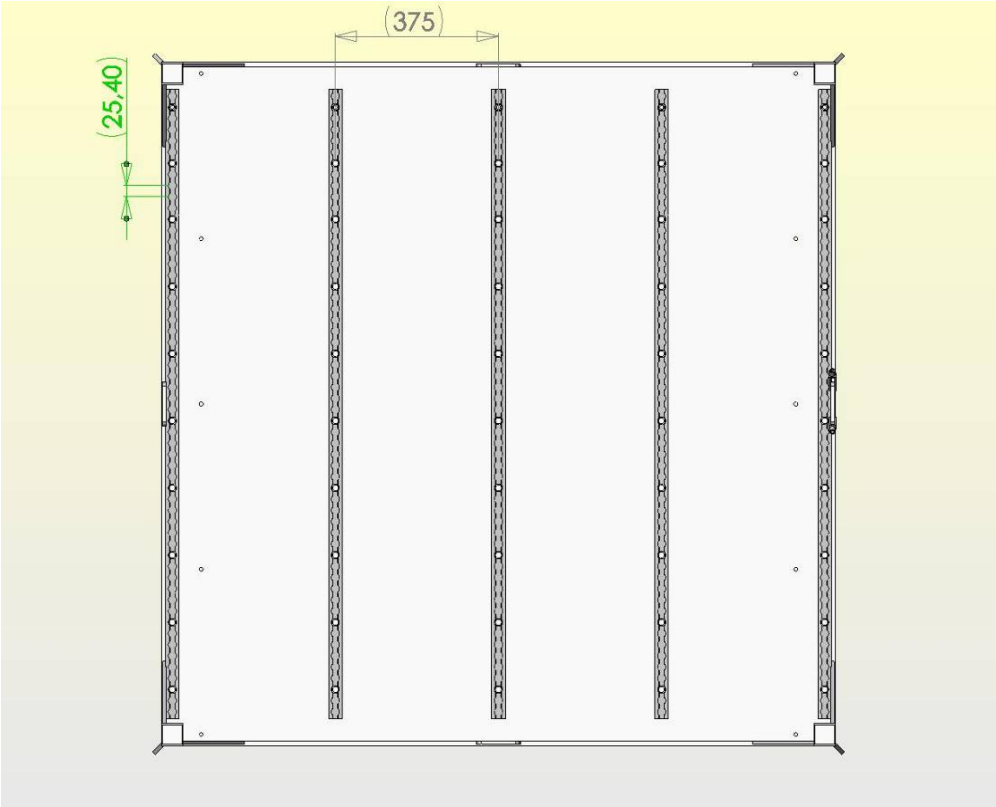

Figure A-2 Egon gondola with rails

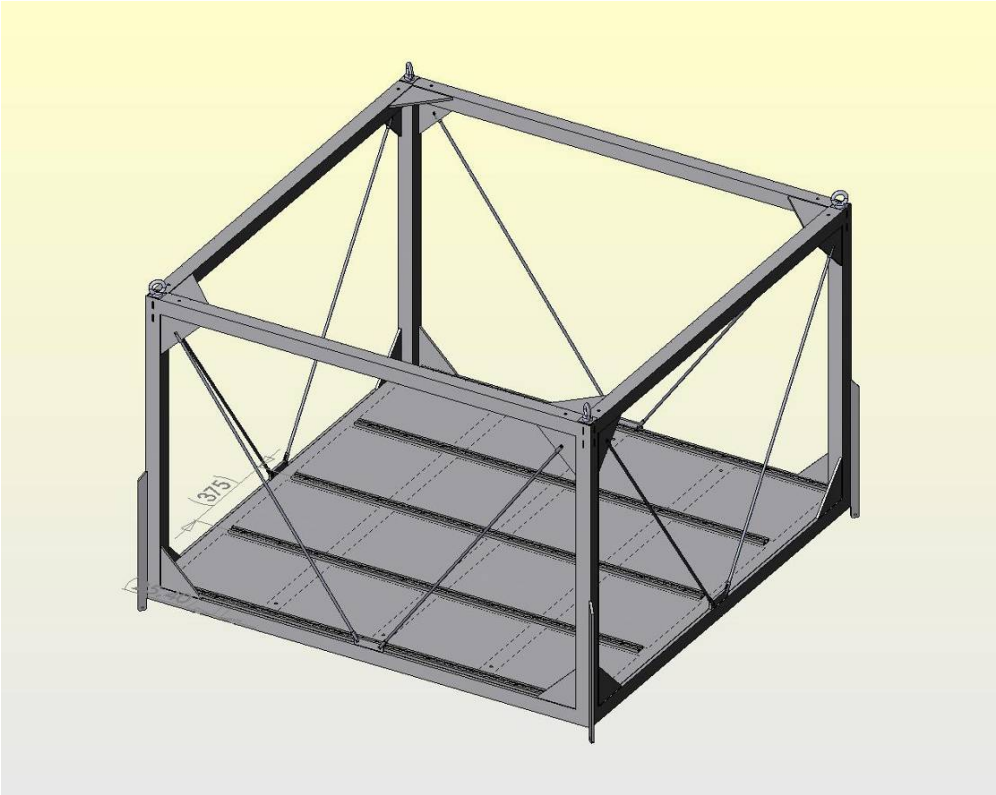

Figure A-3 Egon

APPENDIX B.
ESRANGE SAFETY AND SECURITY COMPLIANCE CONFIRMATION – BALLOON

This document clarifies the basic safety and security conditions for the campaign

…….…….. at the Esrange Space Center.

This document shall be signed by the customer's (range user's/prime contractor's) Mission Manager/Project Manager and by the Esrange Project Manager. One copy of this document and of the *Esrange Safety Manual* (ESM, EUA00-E538), is submitted to the customer's Mission Manager/Project Manager.

Swedish law and Swedish safety and security regulations apply to all activities at Esrange.

The *Esrange Safety Manual* provides safety regulations and criteria associated with launching of sounding rockets, UAV´s and stratospheric balloons and must be followed by all parties involved.

Temporary and complementary regulations may be issued at any time via the Esrange Project Manager and conveyed to the Mission Manager/Project Manager.

If the customer has own rules that are more stringent, the customer's rules shall be respected when relevant and applicable.

Customer Positions and Responsibilities

Mission Manager/Project Manager is responsible for the customer's work at Esrange and is responsible to see that all customer and customer's contractor personnel follow existing rules and instructions. He/she is the contact point between the customer and Esrange.

SSC Esrange Positions and Responsibilities

Esrange Project Manager is responsible for the campaign coordination at Esrange and is the contact point between Esrange and the customer. He/she shall also superintend all safety and security regulations and arrangements related to the campaign.

Head of Esrange Launch Team is responsible for the ground safety in the launch areas and also all work with explosives at Esrange.

Operations Officer (OP) coordinates all operational work and is the interface with the customer and with Swedish and foreign authorities during **countdown**, **flight and recovery**.

Safety Officer/Flight Control Officer (SO) is responsible for flight safety during **countdown and flight**. He/she decides in coordination with the customer when to abort a flight.

Launch Officer (LO) is during **countdown** responsible for the ground safety in the launch areas and also all work with explosives at Esrange.

We accept the content of the text above.

Date ……

……..……..	……..
Customer Mission Manager/Project Manager	Esrange Project Manager

APPENDIX C.
GONDOLA/EXPERIMENT INTERFACE IMAGES

Figure C-1 BEXUS 8 exterior with experiment equipment mounted to the outside of the Gondola

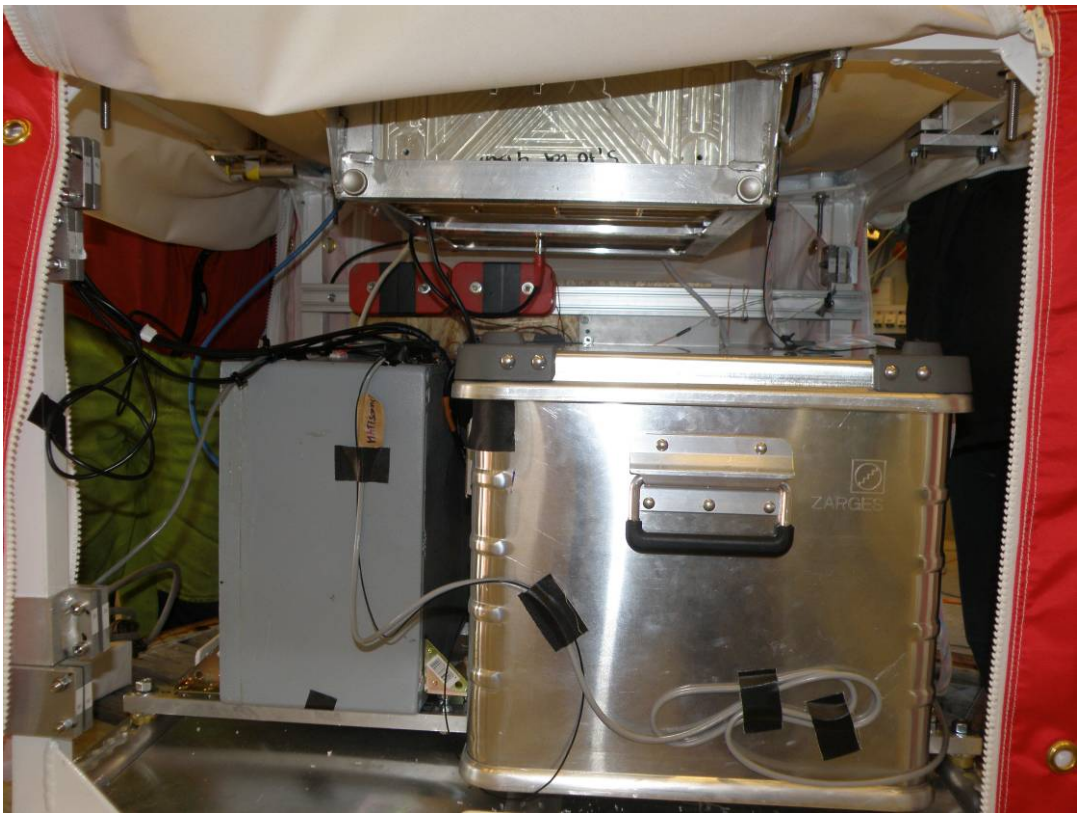

Figure C-3 BEXUS 8 interior showing connections to gondola frame and rails

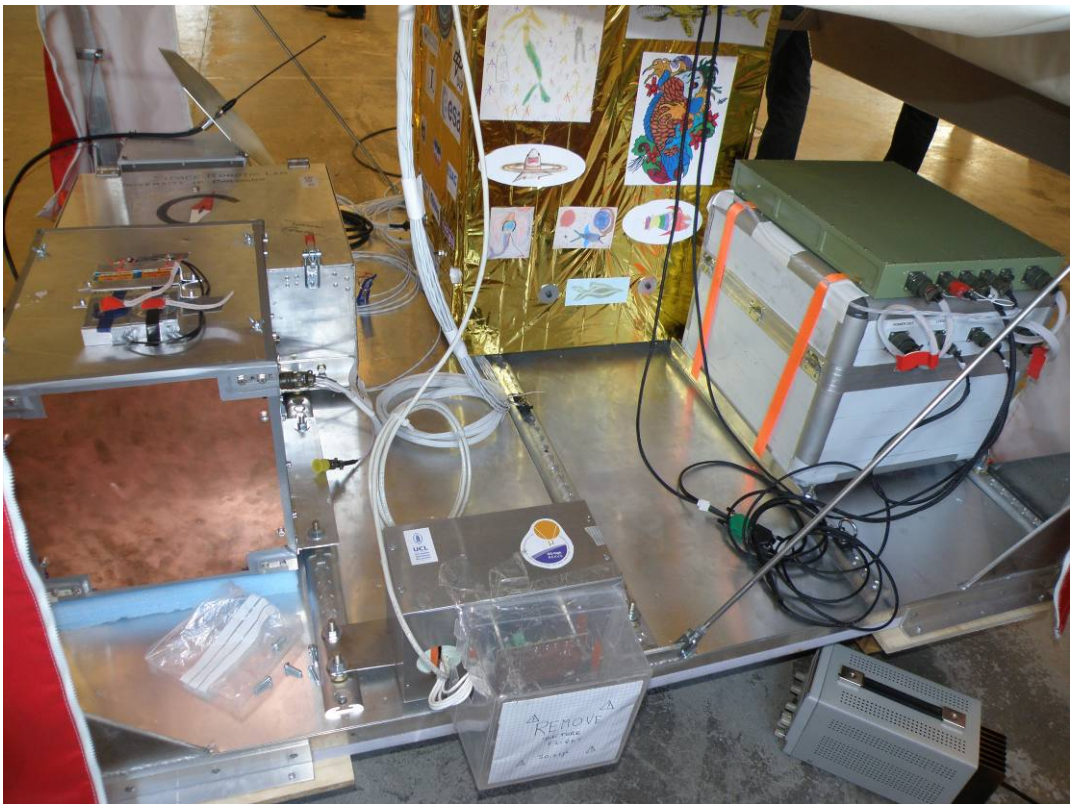

Figure C-2 BEXUS 9 showing 4 different mounting techniques for mounting to rails